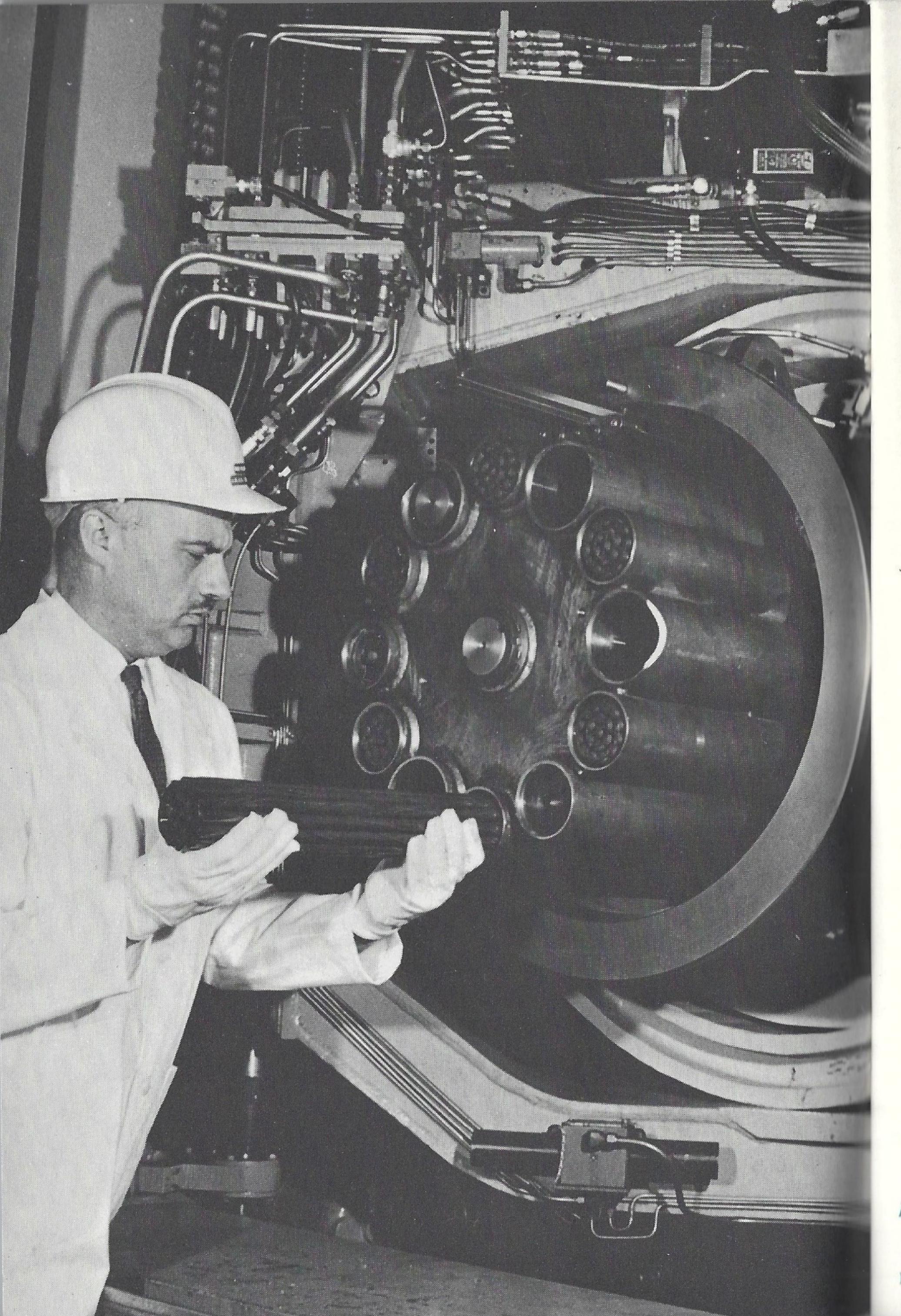
101 ATOMIC TERMS AND WHAT THEY MEAN



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Inspecting one of the two fuelling machines for Douglas Point station.

Photo: Atomic Energy of Canada

INTRODUCTION

The petroleum industry uses atomic energy in important phases of its work. Radioisotopes aid in exploration for new sources of oil and in pipeline transportation. Atomic energy is being used more broadly in research and engineering to develop oil and chemical products and processes. Neutron generators help analyze chemical compounds. In radiation laboratories, radioactive materials such as cobalt-60 assist in triggering new chemical reactions that may lead to useful materials.

This booklet is designed to help you share our interest in this exciting and promising area of science. It is adapted from an original publication of the Esso Research and Engineering Company, with terms and illustrations appropriate to Canada prepared in cooperation with Atomic Energy of Canada Limited. Italics indicate key words defined in this glossary.

Imperial Oil Limited May 27, 1966 "A" Symbol for mass number, that is, the number of protons plus the number of the neutrons in the nucleus. The mass number is approximately equal to the atomic weight. For example, "A" is 1 for hydrogen, 2 for deuterium and 235 for uranium.

ACCELERATOR A device for imparting very high velocity to charged particles such as electrons or protons. These fast particles can penetrate matter and are types of radiation. Fast particles of this type are used in research or to study the structure of the atom itself. Some accelerators are called atom smashers. (Turn to Page for a listing of accelerators and reactors by type.)

ACTIVATION Making a substance artificially *radioactive* in an accelerator such as a cyclotron or by bombarding it with neutrons in a reactor.

ALPHA PARTICLE (alpha ray, alpha radiation). A small electrically charged particle of very high velocity thrown off by many radioactive materials, including uranium and radium. It is identical with the nucleus of a helium atom and is made up of two neutrons and two protons. Its electric charge is positive and twice as great as that of an electron.

ANTI-PARTICLE A particle which interacts with its counterpart of the same *mass* but opposite electric *charge* and magnetic properties, (e.g.: *proton* and anti-proton or *neutron* and anti-neutron) with complete annihilation of both and production of an equivalent amount of *radiation* energy. The *positron* and its anti-particle, the *electron*, annihilate each other upon interaction and produce *gamma rays*.

Italics indicate key words defined in this glossary.

ATOM The tiny "building block" of nature. All materials are made of atoms. The *elements*, such as iron, lead and sulphur, differ from each other because they contain different atoms. There are six sextillion (6 followed by 21 zeros) atoms in an ordinary drop of water. The word "atom" comes from the Greek word meaning indivisible. Now we know it can be broken down and consists of an inner core (*nucleus*) surrounded by *electrons* which rotate around the nucleus something like the planets around the sun.

ATOMIC ENERGY Energy released in *nuclear reactions*. Of particular interest is the energy released when an atom's *nucleus* splits into smaller pieces (fission) or when two nuclei are joined together at temperatures of several hundred million degrees (fusion). "Atomic energy" is really a popular misnomer. It is more correctly called "nuclear energy".

ATOMIC NUMBER The number of *protons* (positively charged particles) found in the *nucleus* of an *atom*. All *elements* have different atomic numbers. The atomic number of hydrogen is 1, that of oxygen 8, iron 26, lead 82, *uranium* 92. The atomic number is also called *charge number* and is usually denoted by Z.

of the number of *protons* and *neutrons* found in the *nucleus* of an *atom*. This sum is also called *mass number*. The atomic weight of oxygen, for example, is approximately 16, with most oxygen atoms containing 8 neutrons plus 8 protons. Aluminum is 27, it contains 14 neutrons and 13 protons.



The 200,000 kilowatt Douglas Point nuclear power station on the shore of Lake Huron in Bruce County, Ont.

AUTORADIOGRAPHY Self-portraits showing the distribution of radioactive material in an object made by placing the object close to a photographic film. The radiations fog the film leaving an image of the distribution of the source. It was such self-portraits that led to the discovery of radioactivity.

BACKGROUND The radiation coming from sources other than the radioactive material to be measured. This background comes in part from naturally radioactive substances on earth and is in part due to cosmic rays which constantly bombard the earth from outer space.

particle thrown off by many radioactive materials. It is identical with the electron and possesses the smallest negative electric charge found thus far in nature. Beta particles emerge from radioactive material at high speeds, sometimes close to the speed of light.

BINDING ENERGY The energy which holds the neutrons and protons of an atomic nucleus together.

BREEDER A reactor which is producing more atomic fuel than it is consuming. Some nonfissionable nuclei bombarded by neutrons can be transformed into a fissionable material, such as plutonium, which can be used as fuel. Scientists are working toward the day when all the material burned in reactors will be replaced through this process. See converter.

BUBBLE CHAMBER A chamber containing a liquefied gas such as liquid hydrogen, under conditions such that a *charged* particle passing through the liquid forms a trail of bubbles along its path which is thus made visible.

BURN-UP The extent to which the initial fissile material in a fuel element has been consumed by fission.

CAPTURE The process of increasing the *mass* of a *nucleus* by the absorption of another particle, e.g.: *neutron*, *alpha particle*, *electron*, etc. Frequently the resulting *isotope* is *radioactive* and most *radioisotopes* are produced from the capture of neutrons by stable isotopes in a *reactor*.

CASK (flask). A thick-walled container (usually lead) used for transporting or storing radioactive materials.

CESIUM-137 An isotope of the element cesium having a mass number of 137. One of the important fission products and a constituent of fall-out. It has a half-life of 30 years.

CHAIN REACTION When a fissionable nucleus is split by a neutron it releases energy and one or more neutrons. These neutrons split other fissionable nuclei releasing more energy and more neutrons making the reaction self-sustaining (as long as there are enough fissionable nuclei present).

CHARGE The electric charge of a *nucleus* is proportional to the number of *protons*. For example, the charge on *deuteron* is 1, the charge on a *uranium* nucleus is 92.

CLOUD CHAMBER A glass-domed chamber filled with vapour under conditions such that a *charged particle* passing through it leaves a track of condensation much like the vapour trail of a jet plane and showing the path of the particle. The cloud chamber and *bubble chamber* serve the same purpose.

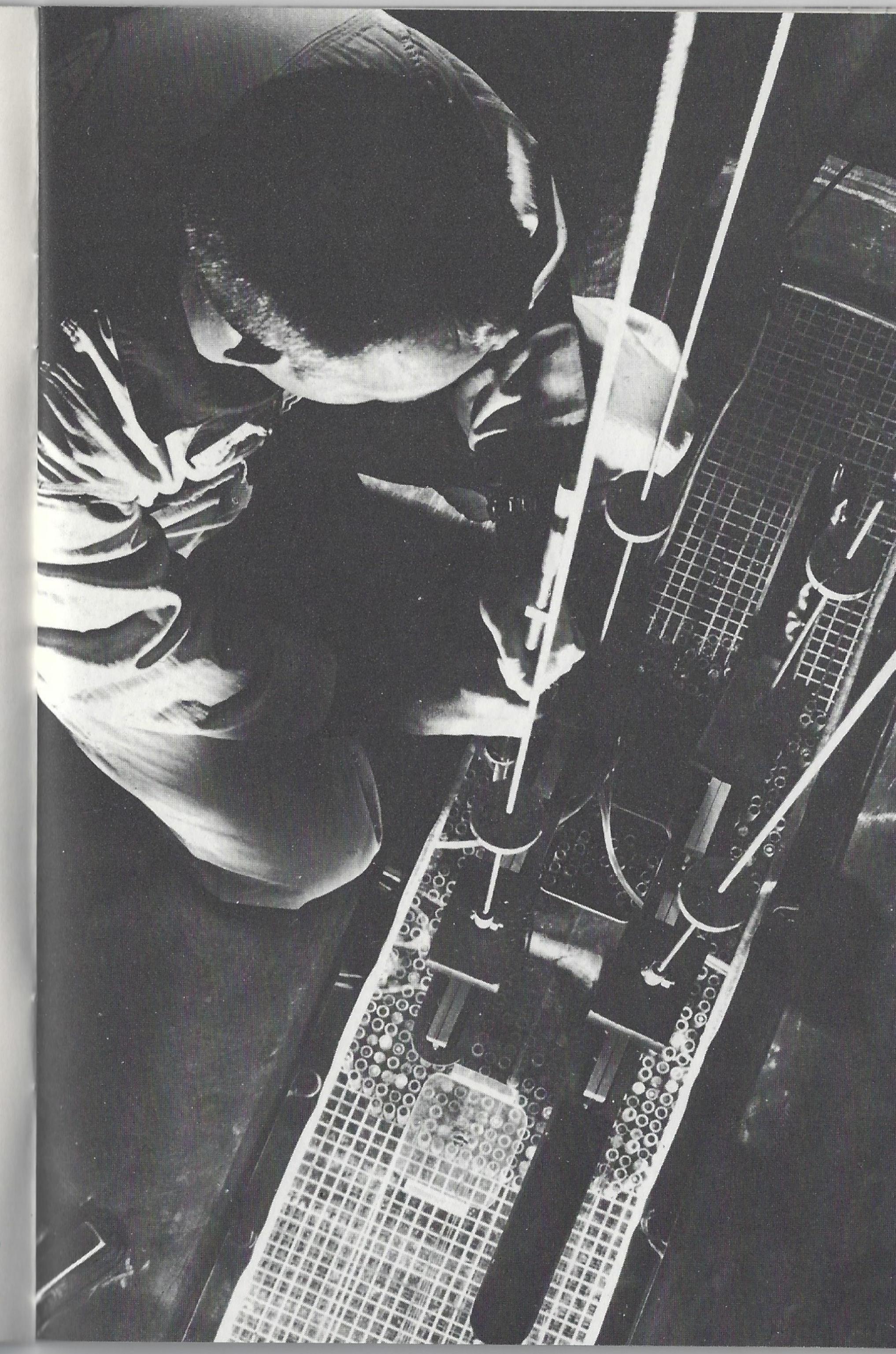
COBALT-60 A radioactive isotope of the element cobalt. Cobalt-60 is important as one of the least expensive sources of gamma radiation and is used widely in research, industry and radiotherapy.

COMPTON EFFECT The glancing collision of a gamma ray with an electron. The gamma ray gives up part of its energy to the electron. The name is taken from the discoverer, Dr. Arthur Compton.

control Rod A rod, containing an element such as boron, used to control the power of a nuclear reactor. The control rod absorbs neutrons which would normally split the fuel nuclei. Pushing the rod into the reactor core reduces the release of atomic power. Pulling out the rod increases it.

CONVERTER A nuclear reactor which produces new fuel (fissile material) from fertile material nearly as fast as it burns it up. For example, a natural uranium-heavy water reactor consumes U-235 and produces plutonium from U-238. A breeder produces more fissile material than it consumes.

COOLANT The coolant fluid transfers the heat which is produced in the *core* of the *reactor* to the outside. In a power produc-



ing reactor, this heat is then utilized by standard methods to do work. The coolant may be water, steam, hydrocarbons, or gases such as helium or carbon dioxide.

core The heart of a nuclear reactor where the nuclei of the fuel split (fission) and release energy. The core is usually surrounded by a reflecting material, such as graphite or water, which bounces escaping neutrons back to the fuel. It is usually made up of fuel elements and a moderator.

counter A device for detecting nuclear disintegrations to measure radioactivity. The signal which announces a disintegration is called a count. A Geiger counter is a gas-filled electrical device which detects the presence of an atomic particle or ray by the ions it produces. A scintillation counter is a device for counting atomic particles or rays by means of tiny flashes of light (scintillations) which the particles produce when they strike certain crystals or liquids.

CRITICAL MASS The amount of nuclear fuel necessary to sustain a chain reaction. If too little fuel is present too many neutrons will escape and the reaction cannot be sustained.

curie. It is named for Pierre and Marie Curie, pioneers in radio-activity and discoverers of the elements radium, radon, and polonium. One curie corresponds to 37 billion disintegrations per second.



CROSS SECTION The chance that a nuclear reaction will take place is measured by the reaction's cross-section. It is the area of an imaginary disc forming the target which a bombarding particle must strike to cause the reactions to take place. Cross sections are very small areas and are measured in multiples of 10⁻²⁴ square centimetres. This unit is called the barn.

DECAY When a radioactive atom disintegrates it is said to decay. What remains is a different isotope of the same element or, nearly always, a different element. An atom of polonium decays to form lead, ejecting an alpha particle in the process. Cobalt-60 decays by the emission of a beta particle and some gamma radiation to become Nickel 60.

The nucleus of heavy hydrogen is a deuteron. Deuterium is called heavy hydrogen because it weighs twice as much as ordinary hydrogen. A deuteron contains one proton and one neutron whereas the hydrogen nucleus contains only one proton. Deuterons are often used for the bombardment of other nuclei.

DOSIMETER (dose meter). An instrument used to determine the *radiation* dose delivered to a specific person or area.

ELECTRON A minute atomic particle possessing the smallest amount of negative electric *charge* found thus far in nature. The electric charge of the *proton* is just as large as that of the electron but is positive. In an *atom*, electrons rotate around a small *nucleus*. The *mass* of an electron is only about a two-thousandth the mass of a proton or *neutron*.

gains this much energy when it is acted upon by one volt. In nuclear science, very high energies have been used. When electrons are accelerated through a billion volts or more they attain correspondingly higher energies and travel at speeds approaching the speed of light — 186,000 miles per second. (See page 29)

ELEMENT A substance made up of *atoms* all having the same *atomic number*. Hydrogen, oxygen and *uranium* are all elements. Many elements consist of a mixture of *isotopes*, which all have the same *atomic number* and the same chemical properties but have different *mass numbers*.

ENRICHMENT The process of increasing the natural composition of the *isotopes* of an *element* to suit a particular purpose. For example, *neutron counters* frequently contain Boron in which the percentage of Boron-10 has been increased in order to improve the detection efficiency. Frequently *reactors* are charged with *uranium* in which the percentage of the *fissile* isotope Uranium-235 has been increased in order to permit the use of a less efficient *moderator* such as natural water rather than *heavy water* or graphite.

FALLOUT Dust particles which contain radioactive fission products resulting from a nuclear explosion. The wind can carry fallout particles many miles.

FERTILE A fertile material is a material which cannot itself sustain a *chain reaction* but which, by a process of *neutron capture* in a *reactor*, can be converted into a *fissile* (fissionable) *nucleus*. Thorium 232 and *uranium* 238 are fertile substances which convert to uranium 233 and plutonium 239.

FILM BADGE A piece of masked photographic film worn like a badge by nuclear workers. It is darkened by nuclear radiation, and radiation exposure can be checked by inspecting the film.

FISSION The division of an atomic nucleus into two parts accompanied by the release of a large amount of radiation and heat.

FISSIONABLE (Fissile). A nucleus which may be divided (fissioned) by the interaction of a neutron.

FISSION PRODUCTS The nuclides produced either by fission or by the subsequent radioactive decay of the nuclides so formed.

FUEL The fissionable material consumed in a nuclear reactor.

FUEL ELEMENT The form in which fuel is introduced into a reactor, commonly in rods, plates, or pellets.

FUSION The joining of atomic nuclei to form a heavier nucleus. If two nuclei of light atoms fuse, the fusion is accompanied by the release of a great deal of energy. The energy of the sun is believed to be derived from the fusion of hydrogen atoms to form helium.

GAMMA RAYS The most penetrating of all useful forms of radiation emitted by a radioactive substance. See X-rays.

HALF-LIFE A means of classifying the rate of decay of radio-isotopes according to the time it takes them to lose half their strength (intensity). Half-lifes range from fractions of seconds to billions of years. Cobalt-60, for example, has a half-life of 5.3 years. A radioactive material loses half its strength in a period of time equal to its half-life.

HEAVY HYDROGEN AND HEAVY WATER Heavy hydrogen is the same as deuterium. Heavy water is water which contains heavy hydrogen instead of ordinary hydrogen. It is used in reactors as a moderator and coolant.

HOT. A colloquial term meaning highly radioactive.

ION Usually an atom which has lost one or more of its electrons and is left with a positive electrical charge. There are also negative ions, which have gained one or more extra electrons.

IONIZATION CHAMBER A device roughly similar to a Geiger counter and used to measure radioactivity.

ISOTOPE A member of a family of *nuclides* each having the same *atomic number* as the others but each having its own *mass number*. In nature, most of the *elements* are made up of several isotopes. Many more isotopes have been made artificially. Those that are *radioactive* are often called *radioisotopes*.

MANIPULATORS Mechanical hands or tongs used to handle hot materials. They are remotely controlled from behind a protective shield.

MASS NUMBER The number of neutrons plus the number of protons in a nucleus. Its symbol is A.

MESON A particle which weighs more than the *electron* but generally less than the *proton*. Mesons can be produced artificially. They are also produced by cosmic *radiation* (natural radiation coming from outer space).

MODERATOR A material used to slow down *neutrons* in a reactor. These slow neutrons are particularly effective in causing fission. Neutrons are slowed down when they collide with nuclei of light elements such as hydrogen, deuterium and carbon, three common moderators.

MONITOR A radiation detector used to determine whether an area is safe for workers.

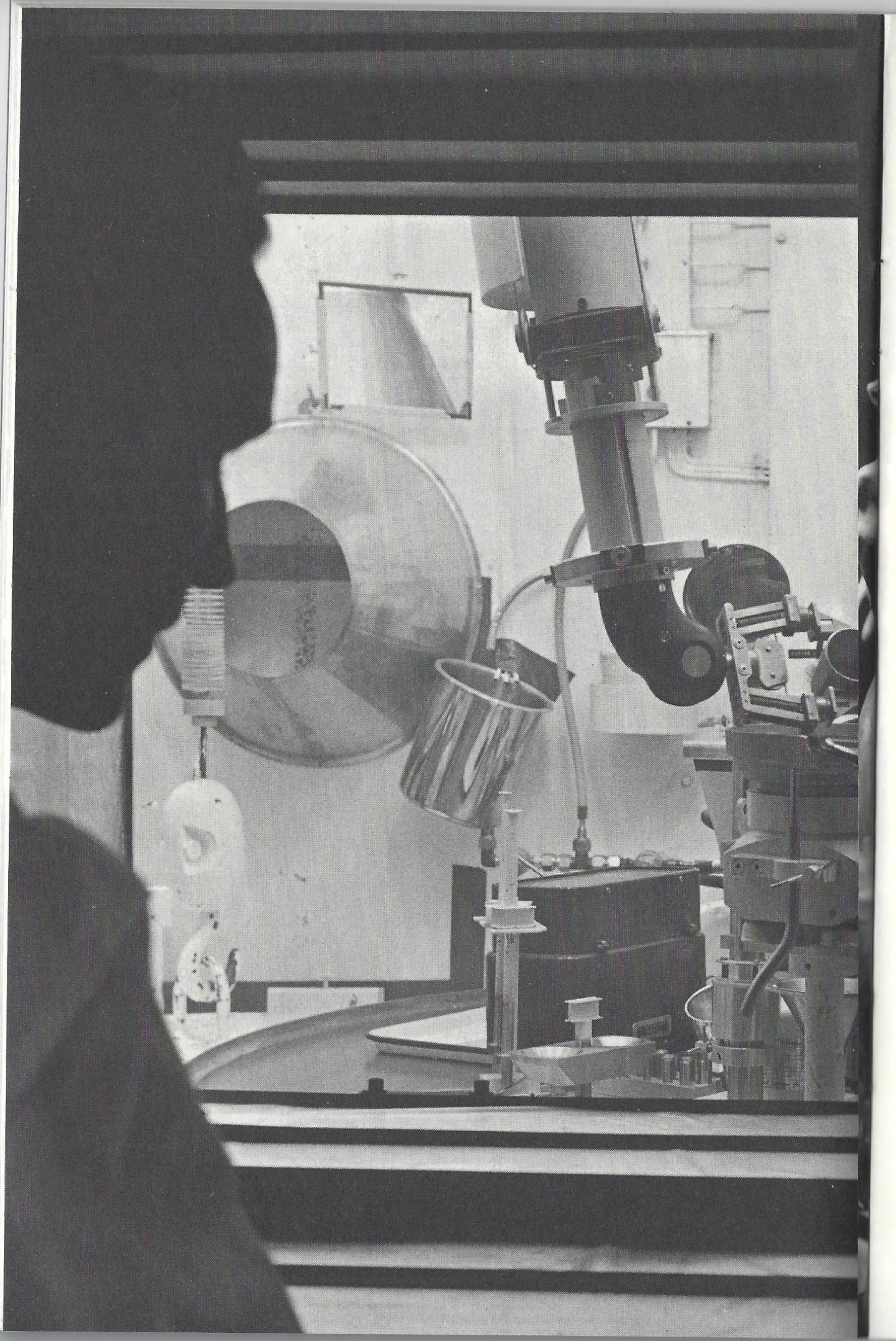
MWd Megawatt days, usually per ton. The amount of energy obtained from one million watts of power in one day. This unit is used normally to indicate the total energy produced in a reactor in a period of time. One megawatt day per ton is the amount of energy expressed in megawatt days, produced from one ton of nuclear fuel. It indicates the extent of burn-up of nuclear fuel. 10,000 MWd per ton is about one per cent burn-up.

NEUTRINO A particle resulting from *nuclear reactions* which carries energy away from the system but has no *mass* or *charge*, and can pass freely through matter.

NEUTRON One of the three basic atomic particles. The neutron weighs about the same as the *proton* and, as its name implies, has no electric *charge*. The free neutron is unstable, having a *half-life* of about 12 minutes, and *decays* to a proton.

NUCLEAR ENERGY The energy released in a nuclear reaction, such as fission or fusion. Nuclear energy is popularly, though mistakenly, called atomic energy.

The electromagnetic isotope separator at the Chalk River nuclear laboratories.



NUCLEAR EXPLOSION The rapid fissioning of a large amount of fissionable material. It creates an intense heat and light flash, a heavy blast, and a large amount of radioactive fission products. These may be attached to dust and debris forming fallout. Nuclear explosions also result from nuclear fusion, which does not give radioactive fission products.

NUCLEAR REACTION Result of the bombardment of a nucleus with sub-atomic particles or very high energy radiation. Possible reactions are emission of a particle different from the bombarding particle or the splitting of the nucleus (fission). The decay of a radioactive material is called a nuclear reaction. Fusion is also a nuclear reaction.

NUCLEONICS The application of nuclear science and techniques in physics, chemistry, astronomy, biology, industry and other fields.

NUCLEUS The inner core of the atom. It consists of neutrons and protons tightly locked together.

NUCLIDE An individual atomic species uniquely described by the number of *protons* and the number of *neutrons* contained in the *nucleus*.

PHOTON A bundle (quantum) of radiation. X-rays, gamma rays and light all consist of photons.

PITCHBLENDE An ore containing both uranium and radium. The Curies had to purify tons of pitchblende to obtain a barely visible speck of radium.

Using remote manipulators to load a container with radioactive Cobalt-60.

PLUTONIUM A heavy element which undergoes fission under the impact of neutrons. It is a useful fuel in nuclear reactors. Plutonium, found in nature only in trace quantities, can be produced and "burned" in reactors.

POISON A material introduced into the *reactor core* to absorb neutrons. The *element* boron is a popular poison, and is used in *control rods*.

positron A particle which has the same weight and charge as an electron but is electrically positive rather than negative. The positron's existence was predicted in theory a few years before it was actually detected. It is not stable in matter since it reacts readily with an electron to give two gamma rays.

PROTON One of the basic particles of the atomic *nucleus* (the other is the *neutron*). Its *charge* is equal to that of the *electron* but positive. The simplest atomic species is an *isotope* of hydrogen whose nucleus contains only one *proton*. See *Deuterium*.

RABBIT A capsule which rapidly carries samples in and out of an atomic reactor or accelerator through a pneumatic or hydraulic tube. Purpose is to permit study of the immediate effect of intense radiation upon various materials.

RAD The standard unit of radiation dose. The Atomic Energy Control Board has established conservative limits of permissible dose for the protection of atomic workers.

RADIATION The emission of swiftly moving particles and photons by radioactive nuclei and also the emission of photons by

stable substances when they are struck by high energy electrons. Alpha and beta particles are emitted by radioactive nuclides and the photon radiation they emit is called gamma radiation. The photon radiation resulting from electron bombardment is called X-radiation.

RADIOACTIVE The property of an isotope or element which is characterized by spontaneous emission of radiation.

RADIOCHEMISTRY That phase of chemistry concerned with the properties and behaviour of radioactive materials.

RADIOISOTOPE A radioactive isotope of an element. A radioisotope can be produced by placing material in a nuclear reactor
and bombarding it with neutrons. Many of the fission products
are radioisotopes. Radioisotopes are sometimes used as tracers, as
energy sources for chemical processing and as radiation sources
for food pasteurization and medical treatment. Radioisotopes are
at present the most widely used outgrowth of atomic research and
are one of the most important peacetime contributions of atomic
energy.

RADIOISOTOPE THERMOELECTRIC GENERATOR A device in which the energy emitted by decay of a radioisotope is converted first to heat and then directly to electricity.

RADIOTHERAPY The use of radiation to treat diseases.

RADIUM One of the earliest known naturally radioactive elements. It is far more radioactive than uranium and is found in the same ores.

REACTOR A nuclear reactor is an "atomic furnace". In a reactor, *nuclei* of the *fuel* are burned (i.e., undergo controlled *fission*) under the influence of *neutrons*, in a *chain reaction*. This energy is removed as heat which may be used to make steam for driving steam engines and to produce electricity. The *moderator* for the first reactor was piled-up blocks of graphite. Thus, a nuclear reactor was formerly referred to as a pile. Reactors are usually classified now as research, test, process heat and power, depending on their principal function. No workable design for a controlled *fusion* reactor has yet been devised.

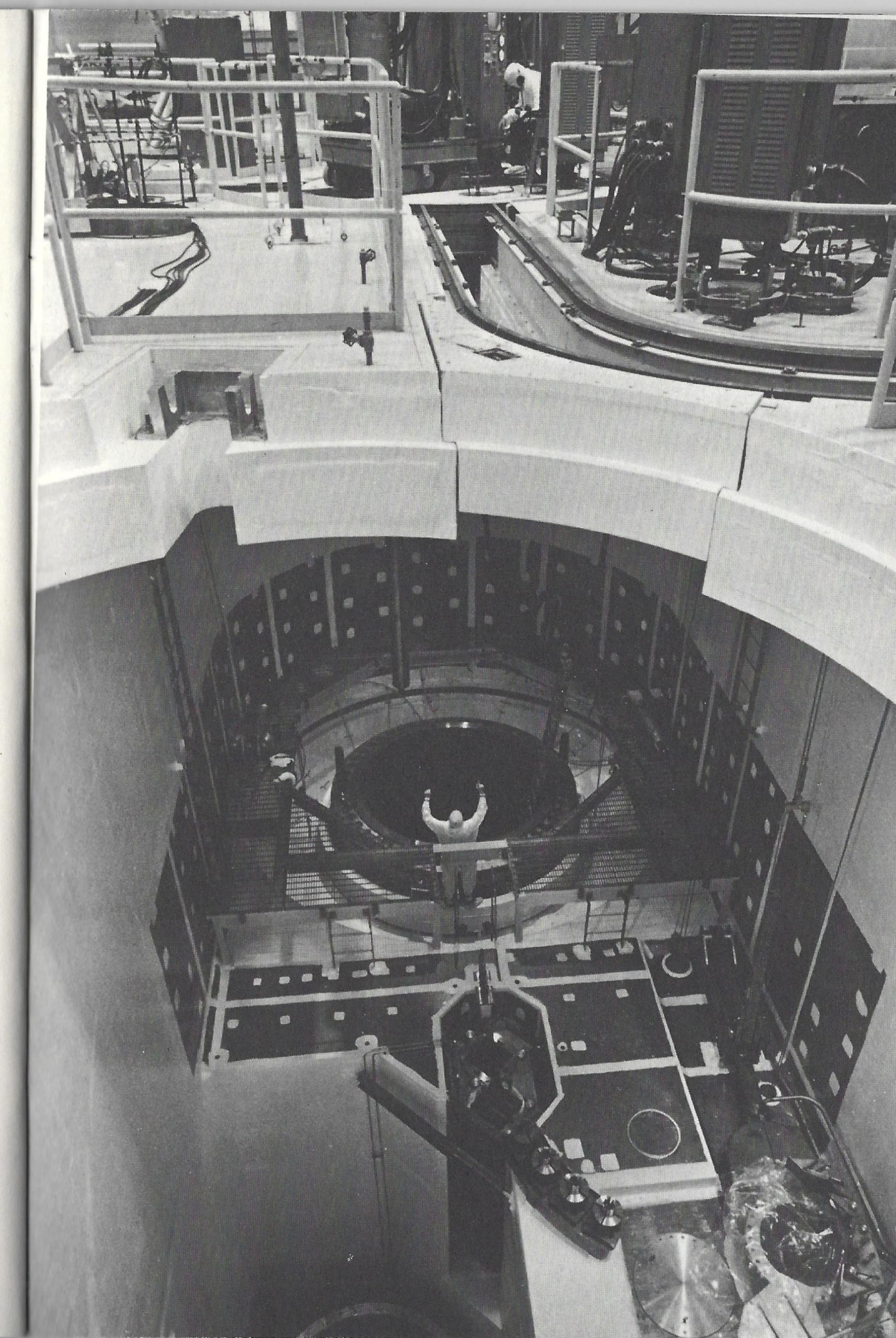
ROENTGEN The standard unit of radiation exposure. The Atomic Energy Control Board has established conservative limits of exposure for the protection of atomic workers.

SHIELD (Shielding). A wall or other layer of dense material which protects workers from harmful radiations released by radioactive materials.

SHUTDOWN Action of a control rod to stop the chain reaction in a reactor. In a liquid moderated reactor, shutdown may be accomplished by removal of some of the moderator.

SOURCE Any substance which emits *radiation*. Usually refers to a piece of *radioactive* material conveniently packaged for scientific or industrial use.

SPARK CHAMBER Similar in purpose to the cloud chamber or bubble chamber. It consists of a series of electrically charged plates. If a charged particle crosses the chamber, the ionization it produces initiates a spark between the plates.



STRONTIUM-90 A radioactive isotope of strontium having a mass number of 90. An important fission product and constituent of fallout. It has a half-life of 25 years.

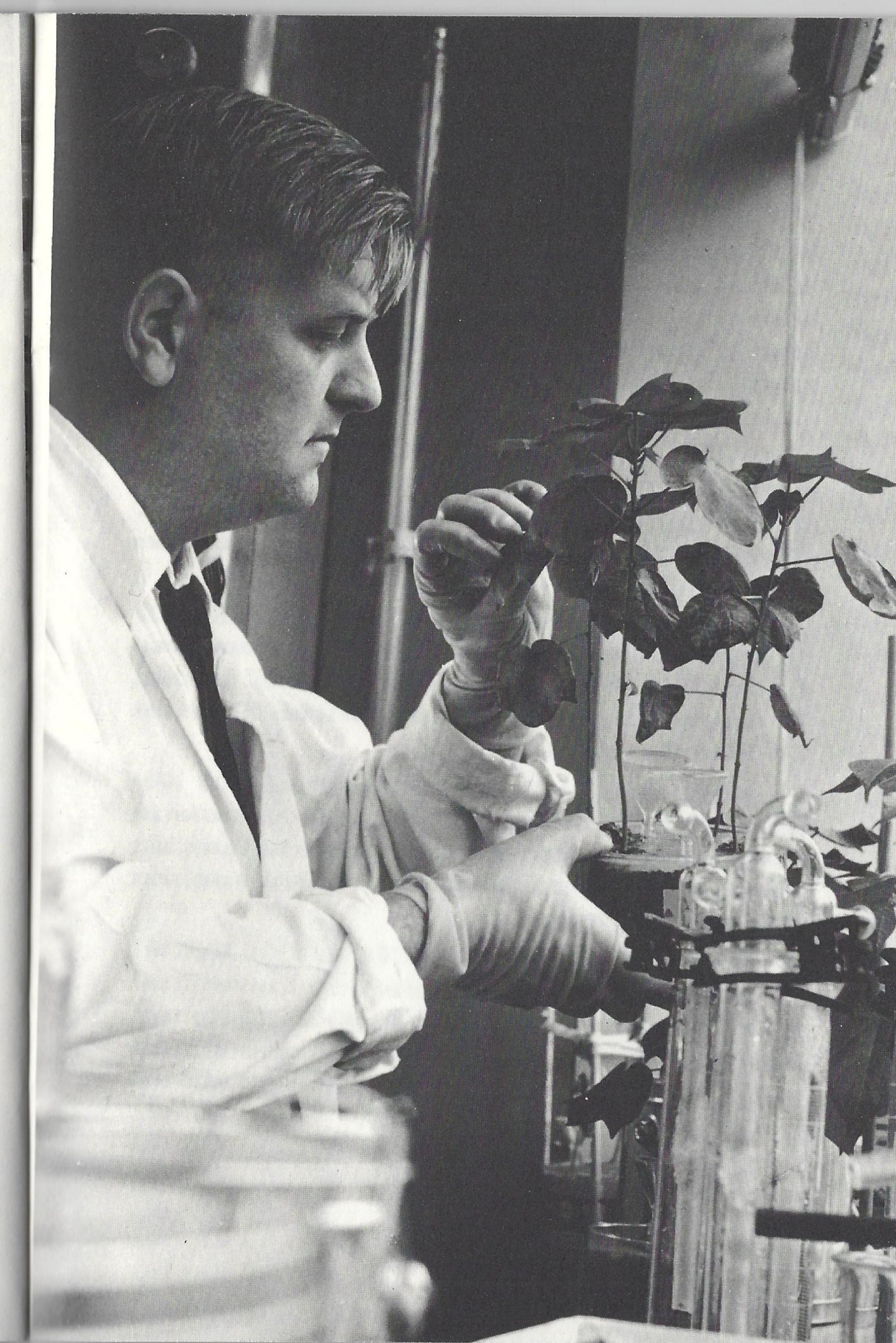
SURVEY METER A portable instrument equipped with a direct reading meter used to determine the level of radiation in an area.

THERMONUCLEAR REACTION A fusion reaction which is produced when the interacting nuclei are contained at an extremely high temperature and which releases a large amount of energy. This is believed to be the sun's source of energy.

THORIUM A heavy *element*. When bombarded with *neutrons* thorium changes into *uranium* 233 which is *fissionable* and thus a source of *nuclear energy*.

TRACER A radioisotope which is mixed in very small proportion with the stable, naturally occurring isotopes of the same element. The radioisotope enables scientists to trace the material as it undergoes chemical and physical changes. Tracers are being used widely in science, medicine, industry and agriculture today. When radioactive phosphorous, for example, is mixed with a chemical fertilizer, the fertilizer can be traced through the plant as it grows. So little of the radioisotope is used that there is no radiation effect upon the process or organism involved.

TRITIUM The third and only radioactive isotope of hydrogen, whose nucleus contains two neutrons and one proton. It exists in nature through production by cosmic radiation and is also produced by neutron capture by deuterium.



UNSTABLE All radioactive elements are unstable since they emit particles and decay to form other elements.

URANIUM A heavy metal. The two principal *isotopes* of natural uranium are U-235 and U-238. U-235 has the only readily *fissionable nucleus* which occurs in appreciable quantities in nature, hence its importance as a nuclear *fuel*. Only 1 part in 140 of natural uranium is U-235.

X-RAY Highly penetrating radiation similar to gamma rays. X-rays do not come from the nucleus of an atom but from surrounding electrons. They are produced by electron bombardment. When these rays pass through an object they give a shadow picture of the denser portions.

"Z" Symbol for atomic number. An element's atomic number is the same as the number of protons found in one of its nuclei. All isotopes of a given element have the same "Z" number. Z = 92 for all uranium isotopes.

ZIRCONIUM A metal which has a low capture cross-section for neutrons. It also has better mechanical and corrosion-resistance properties than aluminum and is therefore a desirable material for structures in a reactor core.

TABLE OF ACCELERATORS AND REACTORS

CYCLOTRON A particle accelerator. In this atomic "merry-go-round" atomic particles such as protons are whirled around in a spiral between the ends of a huge magnet gaining speed with each rotation in preparation for their assault on the target material.

LINEAR ACCELERATOR A machine for speeding up charged particles such as protons and electrons. It differs from other accelerators in that the particles move in a straight line at all times instead of in circles or spirals.

VAN DE GRAAFF ACCELERATOR An electrostatic generator—a particle accelerator. To obtain the voltage, static electricity is picked up at one end of the machine by a rubber belt and carried to the other end where it is stored.

TANDEM ACCELERATOR An accelerator similar to a Van de Graaff accelerator in which the charge of the accelerated ions is reversed after one stage of acceleration so that the same voltage is used to accelerate some of the ions to twice the energy obtainable from the first stage.

NRX (National Research Experimental) A high power research reactor using a heavy water moderator built at Chalk River in 1947.

WR-1 (Whiteshell Reactor No. 1) A high power (40MW) research reactor under construction in 1965 at the Whiteshell Nuclear Research Establishment, Pinawa, Manitoba. It uses enriched uranium oxide fuel, a heavy water moderator and an organic liquid coolant.

NPD (Nuclear Power Demonstration) The first Canadian power reactor for the production of electricity. It produces 20 MW of electrical power and uses natural uranium oxide fuel and a heavy water moderator and coolant.

CANDU (Canadian-Deuterium-Uranium) A high power (200 MW electricity) reactor which uses natural uranium oxide fuel and a heavy water moderator and coolant under construction in 1965 at Douglas Point, Ontario.

swimming pool REACTOR A light water moderated, enriched uranium fuelled reactor which is mounted in a large water tank resembling a swimming pool. The water provides the shielding and at the same time leaves the core easily visible so that experiments on the core may be easily managed. A low power reactor (100 W) of this type has been built at Chalk River and another operating at 1 MW is in operation at McMaster University.

TABLE OF PREFIXES AND UNITS

Factor	Abbreviation	
Nano — 1/1,000,000,000	n	
Micro — 1/1,000,000	μ	
Milli — 1/1,000	m	
Kilo — 1,000	K	
Mega — 1,000,000	M	
Giga — 1,000,000,000	G	
Billion — 1,000,000,000	В	

These prefixes are applied to the units of measurement in common use.

Nanosecond		nS
Kilovolts	_	kV
Giga electron volts		GeV
Megawatts		MW
Milliroentgens	_	mR
Microcuries		μCi

COVER PHOTO:

Cerenkov radiation emitted by Cobalt-60 in fuel rods suspended in water filled storage bay, Chalk River Nuclear laboratories.

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